REMARKS

Claims 1-13 and 15-35 are pending in this application. Claim 14 has been canceled and claim 9 has been amended to incorporate the limitations of former claim 14. Claim 1 has been amended to specify that the tungsten film stack is terminated by a tungsten cap layer. Support for this amendment may be found at Figures 3B, 4A-C and page 16, line 22 - page 17, line 2. No new matter has been added.

Rejections Under 35 U.S.C. § 103

Claims 9-18 were rejected under 35 U.S.C § 103(a) as being unpatentable over Chang et al. U.S. Patent No. 5,028,565 ("Chang") in view of Klaus et al. "Atomically controlled growth of tungsten and tungsten nitride using sequential service reactions" ("Klaus"). Claims 1-8 and 14-18 were rejected under 35 U.S.C § 103(a) as being unpatentable over Chang in view of Klaus and further in view of either Sukharev et al. U.S. Patent No. 5,804,249 ("Sukharev") or Berenbaum et al. U.S. Patent No. 6,066,366 ("Berenbaum"). Applicants respectfully submit that the claims as currently presented are patentable over the cited art.

As indicated above, claim 9 has been amended to incorporate the limitations of former claim 14, which specified that the exposure to nitrogen is delayed until after deposition of the tungsten nucleation layer has begun. The Examiner acknowledges that Chang and Klaus, either alone or in combination, do not teach or suggest this element, but relies upon Berenbaum to supply this element. Applicants submit the one of skill in the art would not be motivated to delay nitrogen exposure during nucleation, as claim 9 requires, because Berenbaum teaches away from such a delay.

Berenbaum teaches depositing tungsten layers by CVD by a method having 3 steps: a nucleation step, an inter-deposition step, and a main deposition step. Experiments 1-4 in Figure 1 of Berenbaum show the results of nitrogen exposure during various stages of the nucleation step including no nitrogen exposure, nitrogen exposure only at the beginning of the nucleation step and delayed exposure. Delaying nitrogen exposure (Experiment 4) resulted in instability. Stable growth was achieved only with no nitrogen (Experiment 2) or nitrogen present only at the onset of the nucleation step (Experiment 3). Because Berenbaum teaches that

delaying nitrogen exposure results in instability, one of skill in the art would have no motivation to modify the processes of Chang and/or Klaus as the Examiner suggests.

For at least the reasons given above, claim 9 as amended is patentable over the cited art. Pending depending claims 10-13 and 15-18 are also patentable for at least these reasons. Accordingly, Applicants request the Examiner withdraw these 35 U.S.C § 103(a) rejections.

Claims 19-35 are directed toward a tungsten deposition process using an initial pulse of a boron-containing reducing agent to form a sacrificial layer of elemental boron on the substrate. This aspect of Applicants' invention dramatically reduces the sensitivity of the deposition process to variations in the incoming semiconductor wafers. In one embodiment, one can even nucleate tungsten on wafer surfaces with discontinuous Ti-TiN line-barrier films (page 18, lines 6-8). Typically, the boron deposition process is not a conventional self-limiting ALD type deposition process (contrast silane-based reactions, for example). Rather, the suitable boron-containing material decomposes thermally to produce a boron film under typical operating conditions on the dielectric surface (page 17, lines 12-16). In some embodiments, due to the particular kinetics of boron growth, a very thin boron film can be deposited as a sacrificial layer (page 18, lines 1-3). It is the particular selection of the boron-containing compound from among reducing agents that provides the advantages of reducing sensitivity to wafer variations.

Chang teaches a CVD process which deposits a film after a vapor-phase reaction. Klaus teaches a conventional ALD method of deposition tungsten using silane as a reducing agent. The Examiner acknowledges that the combined teaching of Chang and Klaus does not teach forming a boron layer on the substrate, but takes Official Notice and that is well known in the art that diborane and silane are equivalently used as reducing agents.

While it is known that both diborane and silane are reducing agents, Applicants traverse the Official Notice that diborane and silane <u>are equivalently used</u> as reducing agents and request that the Examiner supply documentary evidence to support this contention. Note that the claimed invention involves the selection of boron from among the universe of available reducing agents and recognition of boron's value in the claimed process.

Regardless of whether the Examiner is able to supply a reference, Applicants submit that one of skill in the art would not be motivated to modify the combined teaching of Klaus and Chang to arrive at the claimed invention. As Chang teaches CVD deposition of a tungsten a film

after a vapor-phase reaction, the Examiner relies upon Klaus to supply the element of forming a layer of reducing agent on the substrate surface before contacting the substrate with a tungsten compound. Klaus teaches a conventional ALD process, expressly noting that the self-limiting nature of the reactions is advantageous since it results in the same amount of tungsten growth per cycle, regardless of reactant pressure or exposure (page 480, paragraph beginning at the bottom of col. 1). As explained above, unlike silane-based reactions in conventional ALD processes (such as those taught in Klaus), boron deposition is not typically self-limiting but decomposes thermally to produce a boron film under typical PNL operating conditions. Given the very different types of deposition under consideration in Klaus and Chang and the boron dose step of the present invention, Applicants submit that one of skill in the art would not be motivated to modify these references as the Examiner suggests.

At least for these reasons, Applicants submit that claims 19-35 are patentable over the cited art and request that the Examiner withdraw these 35 U.S.C § 103(a) rejections.

Claims 1-8 are directed toward a tungsten deposition process wherein three distinct tungsten layers are deposited on a substrate: a tungsten nucleation layer, a tungsten bulk layer on the nucleation layer deposited by a CVD process; and a tungsten cap layer on the tungsten bulk layer deposited by a PNL deposition technique. As amended, claim 1 specifies that the tungsten film stack is terminated by a tungsten cap layer. In some embodiments, multiple bulk layers are deposited, each capped with a tungsten cap layer. The tungsten film stack thus terminates with a tungsten cap layer. This aspect of Applicants invention serves to further optimize the overall roughness and step coverage of the resulting film stack (page 16, lines 3-4).

The Examiner contends that one of ordinary skill in the art would be motivated to modify Klaus and Chang with Sukharev to adjust the deposition of and optimize the smoothness of the tungsten layers. Applicants submit that one would not be motivated to modify the Klaus and Chang with Sukharev to arrive at the invention as described by claim 1 as amended because none of the references teach or suggest a tungsten film stack terminated by a cap layer.

Sukharev discloses a process of forming a tungsten contact plug on an IC. The process involves sandwiching an amorphous layer of tungsten between bulk layers. The purpose of the amorphous layer is to protect the second bulk layer from seam growth from the first bulk layer and to create nucleation centers for deposition of the second layer (col. 2, lines 51-57; col. 7, lines 30-32). Sukharev discloses that multiple layers may be deposited, however the film stack

always terminates with a bulk layer (col. 7, lines 59-65). Because the purpose of the amorphous layer is to protect the overlying bulk layer and to create nucleation centers for its growth, one of skill in the art would have no motivation for terminating the tungsten film stack with the amorphous layer. Moreover, Sukharev teaches that the amorphous layer is rough, stating that "the amphorization step is marked by poor step coverage and poor conformality" (col. 7, lines 13-18). One of skill in the art would not be motivated to terminate the tungsten film stack with such a layer.

Thus, because Sukharev teaches away from a tungsten film stack terminated with a tungsten cap layer as described in claim 1 as amended, Applicants submit that claims 1-8 are patentable over the cited art and request that the Examiner withdraw these 35 U.S.C § 103(a) rejections.

Conclusion:

In light of the foregoing amendments and remarks, Applicants respectfully submit that all pending claims are now in condition for allowance. Thus, Applicants respectfully request a Notice of Allowance from the Examiner. Should any unresolved issues remain, the Examiner is encouraged to contact the undersigned at the telephone number provided below. No fees appear to be necessary for this Amendment. However, if the Commissioner determines that any fee is due, such fee may be charged to deposit account No. 50-0388 (Order No. NOVLP033X1).

Respectfully submitted,
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